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Assessing Regional Economic Impacts of Recreation Travel from Limited Survey Data

Donald B.K. English and Jean-Claude Thill

Abstract

Regional economic impacts of public recreation facilities are caused by purchases made by households during trip production. Purchases are made near home, en route, or near the recreation site. Locations where en route purchases are made are particularly ill-defined. Surveys that gather trip expenditure data usually only collect home and site locations and travel mileage, with no reference to the actual route taken to the recreation site or where en route purchases are made. The elliptic method uses current survey data to estimate the amount of en route purchases made in any location as a function of the likelihood of travel through that location. The purchase estimates are then aggregated at the level of counties or groups of counties designated in the economic impact analysis.

Introduction

Public land management agencies are increasingly interested in assessing the regional economic impacts of recreation trips to their lands. These impacts are caused by money spent in the local economy by households producing recreational trips (Dean and others 1978, English and Bergstrom 1994, Lieber and Allton 1983). Special attention has been given to small, often rural, multi-county economies around those public lands. A primary reason for this interest is to evaluate whether recreation can be used as a strategy for rural development and income redistribution (Bergstrom and others 1990).

Donald B.K. English is Research Economist, Southern Research Station, USDA Forest Service, 320 Green Street, Athens, GA 30602-2044; and Jean-Claude Thill is Associate Professor, Department of Geography, University of Georgia, Athens, GA 30602-2502.

To complete their economic impact studies, public agencies usually gather data using detailed user surveys. Current survey instruments are primarily concerned with the dollar amounts of purchases of different types of goods and services by visitors and pay little attention to spatial aspects of either the trip or the purchases (Propst and others 1985). Commonly, spatial data on the trip are limited to identifying starting and ending points and total mileage traveled. The route actually followed by the household to reach the recreation site is unknown. Similarly, locational information for expenditures is often no more than whether each purchase was made in the hometown, en route to or from the recreation site, or at the site itself. Thus, locations for purchases made at home or at the site are reasonably well defined, while locations for en route purchases are not. Purchases made while traveling can account for a significant portion of total trip expenditures, particularly for short-term visits (English 1992, Stevens and Rose 1985).

The lack of geographic content in travel expenditure data precludes a direct assessment of the economic impact of en route purchases on regional economies. Analysts must rely on indirect methods to estimate the amount spent by each surveyed household on en route purchases occurring in the regional economy studied. For the remainder of the paper, we use the term "region" to mean the geographic area that contains the economy and "amount" to indicate the dollars spent on purchases.

We assume that the expected amount of purchases that a household makes in a region while traveling to or from the recreation site is directly related to the amount of recreation travel that occurs in the region. No purchases will occur in the region if the household does not travel through it. At the other extreme, if all travel occurs in the region, all purchases

made while traveling must be r... approximation, an equiproport... postulated.

Currently, public agencies use ... spatially allocate purchases. Tl... proportion of en route purchase... same as the proportion of the st... to the recreation site that lies w... others 1990, English 1992). Tl... important assumptions. First, that households only travel in a straight line from home to the recreation site. Second, that the probability of travel through each point on the line is uniform. Our method relaxes both assumptions and makes use of two additional pieces of information: the actual distance the household travels and the shape of the region.

Our main objective was to develop a procedure (elliptic method) that uses more of current survey data (to estimate expenditures in a region). In the following sections we present the theoretical backdrop to the problem, describe the procedure for calculating the expected proportion (probability) of recreation travel through a spatial area, give an empirical example, and provide conclusions.

Theoretical Backdrop

Household production of recreation trips provides the economic basis for regional economic impact analysis (English and Bergstrom 1994). Households combine purchased market inputs with their skills and time to produce and consume trips. Within this context, households attempt to minimize the costs of producing recreation trips (Bockstael and McConnell 1981). These costs include the prices paid for goods and services used during the trip, such as lodging, site entry, or equipment. The costs of goods used while traveling to and from the site, such as food, gasoline, and lodging, and the value of the household's time for traveling and acquiring the purchased goods are also included (Bockstael and others 1987, Clawson and Knetsch 1966). Thus, minimizing trip production costs entails minimizing the time and money costs both of the actual travel and of shopping for and acquiring all purchased inputs (Lentnek and others 1987, Wilman 1980).

The goods most commonly purchased during the travel phase of the recreation trip, food and gasoline, are moderately priced and easily obtained. These characteristics imply highly restricted price search and shopping efforts by households in both time and space, because shopping costs soon outweigh price savings (Eaton and Lipsey 1979). Limited shopping

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...ary for trip production. A ...te that minimizes the generalized travel cost, which is a weighted sum of the monetized value of distance and time, is chosen. Given a featureless plain, households would certainly elect to drive directly to the site. However, the usual circuity of roads makes straight-line travel unlikely. Moreover, minimum mileage routes may not be the fastest routes. Congestion and speed limits may make longer routes less expensive when considering the value of travel time. Therefore, possible travel routes are distributed about the straight line from home to the recreation site. However, as the household tries to minimize its total travel costs, the likelihood that a route is selected away from this line decreases.

Calculating Expected Travel Proportion

In this section, we construct the probability distribution functions of traveling through any location, given the limited data collected in user surveys: the origin, destination, and length of the trip. From these functions we derive the expected proportion of recreation travel through any defined region.

Consider a household taking a trip from its home, I, to recreation site, R, separated by some distance, S. The household chooses a generalized-cost-minimizing travel route of length T, where T > S. The envelope of possible travel routes of length T is an ellipse whose foci are at I and R.

Several general observations can be made about the travel routes within the elliptical envelope. In the absence of external information (such as road locations or what route the household traveled), the distribution of possible travel routes will be symmetrical with respect to both the major and minor axes of the ellipse. The number of unique paths through locations along any line drawn perpendicular to the major axis between the foci of the ellipse decreases away from the axis. The number of routes through locations outside the foci declines rapidly with distance away from the focal point. Any location at the border of the ellipse will be on a single route,

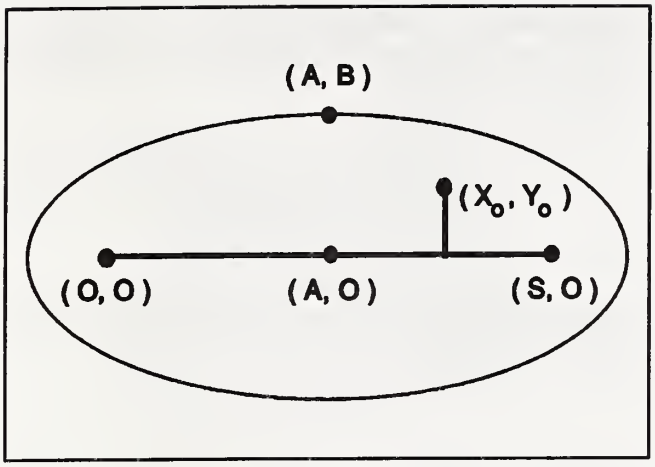

Figure 1—Example of elliptical travel envelope.

consisting of travel directly to that point from home and then directly to the recreation site.

For example, let a household be located at the origin, and (S, 0) be the location of the recreation site.[1] The household travels an actual distance, T. Recreation travel is bound to occur within an ellipse whose foci are (0, 0) and (S, 0) (fig. 1). The goal is to calculate the probability that the household travels through some location, (X_0, Y_0).

The travel distance, T, is also the straight-line distance from home to a point on the ellipse border and then to the recreation site. Let B be half the length of the minor axis for the ellipse, and A be half the straight-line distance between foci, or S/2. The ellipse is centered around the point (A, 0), and (A, B) is a solution to the ellipse. The distance from (0, 0) to (A, B) is T/2. Using the Pythagorean Theorem,

$$\left(\frac{T}{2}\right)^2 = A^2 + B^2 , \tag{1}$$

and rearranging yields

$$B = \sqrt{\frac{T^2}{4} - A^2} , \tag{2}$$

the equation for the ellipse is

$$1 = \frac{(X-A)^2}{\left(\frac{T}{2}\right)^2} + \frac{Y^2}{B^2} . \tag{3}$$

For any X between (A-(T/2)) and (A+(T/2)), two Y values solve the ellipse. One, Y^+, will be greater than zero, and the other, Y^-, will be less than zero. These Y values are:

$$Y^+ = \left|\left(B\sqrt{1 - \frac{(X-A)^2}{\left(\frac{T}{2}\right)^2}}\right)\right| , \tag{4}$$

$$Y^- = -\left|\left(B\sqrt{1 - \frac{(X-A)^2}{\left(\frac{T}{2}\right)^2}}\right)\right| . \tag{5}$$

Equations (4) and (5) define the elliptical envelope of possible routes of length T. This ellipse can be divided into three portions. The central portion includes all points lying between the foci, i.e., all points where the X coordinate is between 0 and S inclusive. The household must travel through this area to get from its home to the recreation site. The remaining two portions lie between the foci and the two end points, where either $X < 0$ or $X > S$. The household may choose to travel through these areas, but need not do so.

Now we investigate the pattern of trips within the defined elliptical envelope. For the central portion of the ellipse, we assume the likelihood of recreation travel through a point within this portion, (X_0, Y_0), is distributed normally along the line perpendicular to the X axis. The probability of travel through that point, pr (X_0, Y_0), is:

$$pr\,(X_0,Y_0) = \left(\frac{1}{\sqrt{2\pi\sigma^2}}\right) \exp\left[-\frac{Y_0^2}{2\sigma^2}\right] , \tag{6}$$

where σ is the standard deviation.

While Y_0 is known, the value of the standard deviation must be determined before the probability can be calculated. We assume that, for any X between 0 and S, the ellipse border is four standard deviations from the X axis. Because the

[1] In the general case, the locations of the household and recreation site could be anywhere. However, coordinates can be transformed to make the example case applicable. The procedures can be found in analytic geometry texts.

absolute vertical distance to the ellipse, Y^+ in equation (4), is greatest at A and declines as X approaches either 0 or S, σ is also a function of X:

$$\sigma_X = \frac{1}{4} Y^+ = +\frac{B}{4} \sqrt{1 - \frac{(X-A)^2}{(\frac{T}{2})^2}} \ . \qquad (7)$$

Calculating the probability of recreation travel through any point in this portion of the ellipse is now possible by substituting equation (7) for σ in equation (6).

Households will only enter the end portions of the ellipse if the route minimizes generalized costs. The further into the end portion a point is located, the less likely the household will travel through it. As a result, the likelihood of travel through a point in an end portion of the ellipse depends on both the point's vertical distance away from the major axis, and on its horizontal distance away from the central portion of the ellipse. In general, because the probabilities for the horizontal and vertical distances are independent, the probability of travel through a point, (X_1,Y_1), in one of the end regions is:

$$pr\,(X_1,Y_1) = pr\,(X_1)\ pr\,(Y_1) \ . \qquad (8)$$

Along the vertical dimension, travel probabilities are still assumed to be normally distributed along the line perpendicular to the major axis. However, if the standard deviation, σ, was calculated by the process developed for the central portion of the ellipse, the value for σ would collapse to zero at the end points of the travel ellipse. To prevent collapse, we hold σ constant for points in the end portion. This constant value, σ_0, is the value obtained for σ from equation (7) when $X = 0$.

For the horizontal dimension, let g(D) denote the probability of travel at any horizontal distance, D, into an end portion of the ellipse:

$$g(D) = \exp\left[-\frac{D^2}{2\sigma^2}\right] = \exp\left[-\frac{32D^2}{(T-S)^2}\right] . \qquad (9)$$

The function, g(D), is the normal density function with the constant term removed, so g(D) approaches unity as D approaches zero. The value for σ for the horizontal dimension is also constant, and set to one-fourth the distance from a focus to the nearest end point of the travel ellipse.

We first consider the left-end portion where $X < 0$. Let (X_1,Y_1) be a point in the left-end portion. The probability of travel through (X_1,Y_1) is:

$$pr\,(X_1,Y_1) = \frac{1}{\sqrt{2\pi\sigma_0^2}} \exp\left[-\left(\frac{Y_1^2}{2\sigma_0^2} + \frac{32X_1^2}{(T-S)^2}\right)\right] \cdot \qquad (10)$$

Similarly, the probability of travel through a point in the right-end portion, (X_2,Y_2), is:

$$pr\,(X_2,Y_2) = \frac{1}{\sqrt{2\pi\sigma_0^2}} \exp\left[-\left(\frac{Y_2^2}{2\sigma_0^2} + \frac{32(X_2-S)^2}{(T-S)^2}\right)\right] \cdot (11)$$

Now, the two-dimensional travel ellipse is transformed into a probability solid, where the height of the surface above any point on the X-Y plane is the probability of travel through the point as calculated by equation (6), (10), or (11), whichever is appropriate. The solid shows the distribution of travel for points within the ellipse (fig. 2). The surface is continuous. Two spikes of maximum travel probability occur at the foci on both sides of the ridge of local maxima saddling the line segment connecting foci, the surface height falls monotonically. Finally, the height declines rapidly in the end portions.

The process of estimating the expected proportion of travel that occurs in the regional economy is analogous to estimating the ratio of the volume of a portion of the travel probability solid to its total volume, where the portion of interest is the intersection of the travel ellipse and the targeted region. To complete this process, we calculate the total and travel probability masses for each portion of the ellipse.

The total probability mass for the entire central portion of the ellipse is:

$$TOTCENTR = \int_{X=0}^{S} \int_{Y=Y^-}^{Y^+} \frac{1}{\sqrt{2\pi\sigma_X^2}} * \exp\left[-\frac{Y^2}{2\sigma_X^2}\right] dY dX \ . \qquad (12)$$

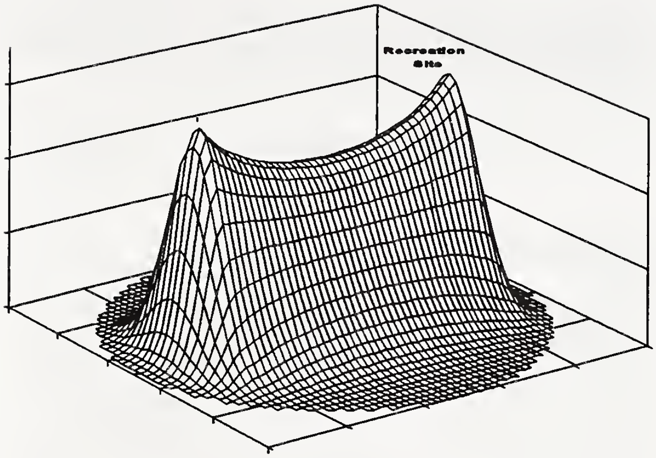

Figure 2—Probability of travel within ellipse.

The total probability mass for the entire left-end portion of the ellipse, TOTLEFT, is:

$$TOTLEFT = \int_{X=(A-\frac{T}{2})}^{0} \int_{Y=Y^-}^{Y^+} \frac{1}{\sqrt{2\pi\sigma_0^2}} * \exp\left[-\left(\frac{Y^2}{2\sigma_0^2} + \frac{32X^2}{(T-S)^2}\right)\right]dYdX \; . \tag{13}$$

And total probability mass for the entire right-end portion of the ellipse, TOTRIGHT, is:

$$TOTRIGHT = \int_{X=S}^{(A+\frac{T}{2})} \int_{Y=Y^-}^{Y^+} \frac{1}{\sqrt{2\pi\sigma_0^2}} * \exp\left[-\left(\frac{Y^2}{2\sigma_0^2} + \frac{32(X-S)^2}{(T-S)^2}\right)\right]dYdX \; . \tag{14}$$

Let the region, Z, be a convex set of points in the X-Y plane[2] (fig. 3). Let X_z^- and X_z^+ be the minimum and maximum, respectively, of the set of X values in the intersection of the travel ellipse and Z. This intersection is the shaded area in figure 3. Also, let Y_z^+ be the "top" of the intersection of Z and the travel ellipse, and Y_z^- be the "bottom," where

$$Y_Z^+ = g_1(X) \le Y^+ \; , \tag{15}$$

$$Y_Z^- = g_2(X) \ge Y^- \; . \tag{16}$$

The travel probability for the central region is:

$$PRCENTER = 0 \; , \qquad if \;\; X_Z^+ < 0 \vee X_Z^- > S \; , \tag{17}$$

$$= \int_{X=0}^{X_Z^+} \int_{Y=Y_Z^-}^{Y_Z^+} \frac{1}{\sqrt{2\pi\sigma_X^2}} \exp\left[-\frac{Y^2}{2\sigma_X^2}\right]dYdX \; , \quad if \; X_Z^- < 0 \wedge X_Z^+ < S \; , \tag{18}$$

$$= \int_{X=0}^{S} \int_{Y=Y_Z^-}^{Y_Z^+} \frac{1}{\sqrt{2\pi\sigma_X^2}} \exp\left[-\frac{Y^2}{2\sigma_X^2}\right]dYdX \; , \quad if \; X_Z^- \le 0 \wedge X_Z^+ \ge S \; , \tag{19}$$

$$= \int_{X=X_Z^-}^{S} \int_{Y=Y_Z^-}^{Y_Z^+} \frac{1}{\sqrt{2\pi\sigma_X^2}} \exp\left[-\frac{Y^2}{2\sigma_X^2}\right]dYdX \; , \quad if \; X_Z^- > 0 \wedge X_Z^+ > S \; . \tag{20}$$

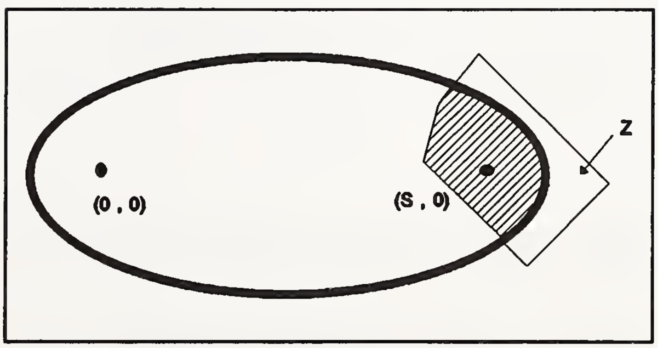

Figure 3—Intersection of region targeted for economic analysis (Z) and travel ellipse.

[2] If region Z is nonconvex, it can be divided into component convex sets. The procedure can then be applied to each component set.

The travel probability for the portion of Z in the left-end region, PRLEFT, is:

$$PRLEFT = 0 \,, \qquad if \;\; X_Z^- > 0 \,, \tag{21}$$

$$= \int_{X=X_Z^-}^{0} \int_{Y=Y_Z^-}^{Y_Z^+} \frac{1}{\sqrt{2\pi\sigma_0^2}} \exp\left[-\left(\frac{Y^2}{2\sigma_0^2} + \frac{32X^2}{(T-S)^2}\right)\right] dYdX \,, \tag{22}$$

$$if \; X_Z^- < 0 < X_Z^+ \,,$$

$$= \int_{X=X_Z^-}^{X_Z^+} \int_{Y=Y_Z^-}^{Y_Z^+} \frac{1}{\sqrt{2\pi\sigma_0^2}} \exp\left[-\left(\frac{Y^2}{2\sigma_0^2} + \frac{32X^2}{(T-S)^2}\right)\right] dYdX \,, \tag{23}$$

$$if \; X_Z^+ < 0 \,.$$

The travel probability in the right-end region, PRRIGHT, is:

$$PRRIGHT = 0 \,, \qquad if \; X_Z^+ < S \,, \tag{24}$$

$$= \int_{X=S}^{X_Z^+} \int_{Y=Y_Z^-}^{Y_Z^+} \frac{1}{\sqrt{2\pi\sigma_0^2}} \exp\left[-\left(\frac{Y^2}{2\sigma_0^2} + \frac{32(X-S)^2}{(T-S)^2}\right)\right] dYdX \,, \tag{25}$$

$$if \; X_Z^- < S < X_Z^+ \,,$$

$$= \int_{X=X_Z^-}^{X_Z^+} \int_{Y=Y_Z^-}^{Y_Z^+} \frac{1}{\sqrt{2\pi\sigma_0^2}} \exp\left[-\left(\frac{Y^2}{2\sigma_0^2} + \frac{32(X-S)^2}{(T-S)^2}\right)\right] dYdX \,, \tag{26}$$

$$if \; X_Z^- > S \,.$$

Finally, the probability of recreation travel occurring within the intersection of Z and the travel ellipse is:

$$PR(Z) = \frac{PRLEFT + PRCENTER + PRRIGHT}{TOTLEFT + TOTCENTR + TOTRIGHT} \,. \tag{27}$$

Thus, for a household I, with total en route trip expenditures E_i, the expected amount of en route purchases made in region Z, E_{Zi}, would be:

$$E_{Zi} = E_i * PR(Z) \,. \tag{28}$$

Empirical Example

We used travel and trip expenditure data from a sample of visitors to five recreation sites during the summer of 1991. The sites included Lolo National Forest (MT), Ozark National Forest (AR), Yuba Lake Recreation Area (UT), Toiyabe National Forest (CA/NV), and Columbia River Gorge National Recreation Area (OR/WA). We were only interested in the behavior of visitors from outside the region, who spent some money while traveling. We did not use data from visitors who reported traveling more than 1,000 miles to the visited site. After culling data from visitors with no determinable home location, 394 observations remained.

Two different configurations for the economic regions surrounding the recreation sites were examined. One was a circle of 50-mile radius. The other was a square, oriented North-South, with the same total area as the circular region. For nonresidents of each regional configuration, we estimated the percentage of trip travel that occurred in the region, for both the ad hoc and elliptic methods (table 1). Estimates of trip expenditures occurring in the region were derived by multiplying reported en route trip expenses by the regional travel probabilities.

Table 1—Estimated portion of recreation travel occurring in target region, by region shape and estimation method

	Regional configuration	
Estimation method	Square	Circular
	Percent	
Ad hoc travel	32.51	36.90
Elliptic travel	29.58	32.58
Difference	2.93	4.32
	Dollars	
Ad hoc travel	\$25.57	\$28.72
Elliptic travel	23.27	25.31
Difference	2.30	3.41

The ad hoc method allocated a greater proportion of recreation travel to the target region than the elliptic method. Differences across the two methods averaged 3 to 4 percent, depending on the shape of the target region. Comparing the methods for an irregularly shaped region could result in even greater differences.

On the average, nonresidents of the example regions reported spending slightly less than $80 while traveling. As calculated by equation (28) and depending on the method used and region shape, we estimated that visitors spent between $23 and $28 in the region while traveling to the site they visited. The percentage differences across the methods translate into expenditure differences of $2.30 or $3.41 per visitor.

Conclusion

Travel is a necessary part of recreation trips. The amount of en route purchases a household makes in a certain region depends on the probability of travel through the region. This paper reported a method for estimating the expected amount of recreation travel through a region, given the limited amount of trip travel data often collected in visitor surveys.

Our elliptic method represents an improvement over the ad hoc methods currently used for estimating the proportion of en route purchases occurring in a region, although it requires no additions to current survey instruments. Less restrictive assumptions about recreation travel are required compared to the current method. In addition, our method both makes use of and is sensitive to the ratio of actual to straight-line travel distances and to the shape of the region.

The results indicate that this new method yields more conservative estimates of the amount of recreation travel and associated purchases that occur in a region. Incorporating this method into procedures used by public land managing agencies, such as the USDA Forest Service, to estimate regional economic impacts of recreation can be readily accomplished. Future research should incorporate information on the number and types of purchase opportunities in a region in estimating en route expenditures. Travel through a region is a necessary but not sufficient condition for making en route purchases in that region. Purchase opportunities must also exist. However, only limited improvements to the method proposed here are possible without first increasing the quality and quantity of trip information contained in user surveys.

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Southern Research Station, P.O. Box 2680, Asheville, NC 28802